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Efficiency of Uniform Standards for Transboundary Pollution Problems: a note

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RESUME

Cette note propose un exemple qui contredit l'idée selon laquelle des pays identiques vont négocier un accord de norme uniforme. Ce travail démontre la proposition suivante: des pays strictement identiques peuvent trouver intérêt à réduire différemment leurs émissions. L'explication de ce résultat trouve son origine dans l'hypothèse de coûts fixes dans la technologie de dépollution. En effet, l'introduction de coûts fixes implique une non-convexité locale de la fonction de coût de dépollution. Des pays identiques peuvent gagner collectivement en signant un accord de normes différenciées afin de profiter des rendements d'échelle dans la dépollution. En revanche, un des pays dépollue pour les deux, et donc paie le coût fixe de l'investissement. En contrepartie, il est compensé pour cet effort par des transferts monétaires. Nous montrons que le niveau des coûts fixes doit être suffisamment élevé dans ce cas.

Mots-clés: pollution transfrontalière, jeux coopératifs, négociation, normes, transferts, coût fixe.

ABSTRACT

This note proposes an example which contradicts the idea that similar countries will negotiate an agreement on a uniform standard. It shows that strictly identical countries may have an interest in reducing their emissions differently, and not in a uniform way. This result relies on the existence of fixed costs in the abatement technology. Identical countries could be better off by signing an agreement on differentiated standards in order to exploit increasing returns to scale in the abatement activities. More specifically, one of the countries abates for both, and pays for the fixed cost of investment. In return, it is compensated by monetary transfers for this effort. We show that the level of fixed cost must be sufficiently high in this case.

Keywords: transboundary pollution, cooperative games, bargaining, standards, transfers, fixed cost.

JEL: Q50, C71.

1 Introduction

Our purpose in this note is to challenge the intuitive argument on the use of uniform standards. This argument defends the use of uniform solutions, because the countries are similar. The idea is that, because the countries have a similar willingness to pay for a cleaner global environment and similar abatement costs, their preferred level of the abatement standard will be the same. Hence it is better to negotiate an agreement on a uniform standard rather than an agreement on differentiated standards. In this note, we mainly ask the following question: what does the existence of a fixed cost of investment in the abatement technology imply, in terms of the comparison of uniform and differentiated standards, when there is a possibility of a side payment scheme¹ across the countries? In order to address this question, we adopt a negotiation game model, and more particularly the Nash bargaining solution (Nash (1950)) as equilibrium.

We define a “rule” in an International Environmental Agreement (hereafter IEA) by the reduction of current emissions to reach a percentage of the emissions of a base year. A uniform rule means that the percentage is the same for all countries. This type of rule is included in the provisions of the Montreal Protocol on Substances that Deplete the Ozone Layer which specified an emission reduction of CFCs and halons by 20 percent based on 1986 emission levels, to be accomplished by 1998 (Finus (2001))². Differentiated rules mean that the percentages are different for different countries. The examples of agreements with differentiated standards are the Kyoto Protocol on Climate Change (1997) and the Oslo Protocol on Further Reduction of Sulphur Emissions (1994). Normally, uniform rules are less flexible, so less efficient than differentiated ones, unless the countries are similar (Harstad (2006), p.2)³. We observe, however, a frequent use of uniform rules in IEAs (Hoel (1991), p.64; Harstad (2006), p.2)⁴.

¹Side payments are offered in order to increase participation in IEAs. The examples of IEAs including the possibility of transfers between countries are the Fur Seal Treaty (1911), the Montreal Protocol (1987) and the Stockholm Convention on Persistent Organic Pollutants (2001).

²Another example is the Helsinki Protocol (1985) which suggested a reduction of sulphur dioxide from 1980 levels by 30 percent by 1993.

³If the countries have different marginal implementation costs, then uniform rules will increase the total cost of attaining a given environmental objective (Hoel (1992), p.142).

⁴One can find in the literature several arguments explaining the use of uniform standards: the fairness argument (Welsch (1992)), the argument of informational problems

Although our analysis is theoretical, nevertheless we can illustrate it by a well-known example: the “Rhine Chlorides case”. This illustration is from Barrett (2003). The Rhine has been polluted by salts since 1930. The bulk of chloride emissions originated in Germany and France. The Netherlands is situated downstream of the other riparian states and in this case was the only victim. In 1972, France, Germany and Switzerland agreed that the reduction would be achieved by France which would store the salt at the cost of FF 100 million. It was decided to split the cost of the investment into four countries (France, Germany, Switzerland and the Netherlands). Although the former three countries were not directly affected by this pollution, the total abatement level achieves utility for moral reasons of “equity” and “solidarity” defined by OECD principles on transfrontier pollution (LeMarquand (1977)) quoted by Barrett (2003, p. 130).

As this example shows, the fixed cost of investment in environmental protection can be a determinant factor of the cooperation across countries. More specifically, the level of the fixed cost can affect the gains from cooperation resulting from several IEA’s. It is possible to justify the existence of such costs in reality, for the case of water pollution by industrial or agricultural activities. For instance, a polluting firm in a country must install a special plant for the cleaning of its discharge. The installation of such a plant represents a fixed cost for the firm. If the level of this cost is high, it would be rational for similar countries, that only one of the countries invests and pays for the fixed cost, and the other country compensates it by side payments. In this study, we construct a model which analyzes the effects of the presence of fixed costs in environmental protection.

We consider two types of institutional arrangements to mitigate a trans-boundary pollution problem across two countries. First, we consider the *reciprocal action case* where the countries undertake the same abatement effort and both pay for the fixed cost of investment in the abatement. This is what we call the agreement on a uniform standard without transfers. Since the countries are identical, there is no need for a side payment scheme. Secondly, we study the *unilateral action case* where only one of the countries undertakes an abatement effort and pays for the fixed cost, and the other country compensates it with transfers. This is what we call the agreement

(Larson and Tobey (1994), Harstad (2006)), the “focal point” argument (Schelling (1960)), the argument of agency problems (Boyer and Laffont (1999)), the trade theory argument (Copeland and Taylor (2005)) and the argument of monetary transfers, even imperfect (Bayramoglu and Jacques (2005)).

on differentiated standards with transfers. This situation could be explained from an economic point of view. It could be more efficient for both countries to avoid the payment of the fixed cost if its level is sufficiently high. This is why the countries could prefer to sign an agreement on differentiated standards with transfers for the high levels of fixed cost.

The paper is organized as follows. Section 2 presents the negotiation model. Respectively, the threat point of negotiations, the agreement on a uniform standard without transfer and the agreement on differentiated standards with transfers are analyzed. Section 3 provides the comparison of the abatement levels resulting from the two agreements. Section 4 represents the comparison of individual welfare across the agreements. Section 5 offers concluding remarks.

2 The Model

The objective of each country is to maximise its utility function with respect to the budget constraint. The program for the country $i = 1, 2$ is written in the following way:

$$\begin{aligned} \underset{a_i}{\text{Max}} NB_i &= \underset{a_i}{\text{Max}} [B(a_1 + a_2) + c] \\ \Omega &\geq c + co + C(a_i) \end{aligned} \tag{1}$$

where NB_i is the utility function of the country $i = 1, 2$, $B(a_1 + a_2)$ represents the benefits from global abatement, c is the consumption of a private good. Ω expresses the exogeneous initial endowments used for the consumption of a private good c , for the fixed cost of investment in the abatement co and for the abatement costs $C(a_i)$.

The global abatement is the sum of the individual abatement efforts of countries 1 and 2 respectively, $a_1 = \bar{E}_1 \times \beta_1$ and $a_2 = \bar{E}_2 \times \beta_2$. The variables \bar{E}_1 , \bar{E}_2 represent respectively the emission levels of countries 1 and 2 in a base year. The variables β_1 , β_2 , with $\beta_1 \leq 1$ and $\beta_2 \leq 1$, are respectively the differentiated percentage emission reduction rates for countries 1 and 2. Since the countries are identical by assumption, the emission levels in a base year are also identical across the countries, i.e. $\bar{E}_1 = \bar{E}_2 = \bar{E}$. We normalize

these emission levels to 1, then (a) is interpreted as a percentage reduction rate of the emissions.

The benefits from global abatement are represented by the function $B(a_1 + a_2)$, assumed to be increasing and concave. The abatement costs are represented by the function $C = co + C(a_i)$. This function is composed of a fixed cost co and a variable cost $C(a_i)$. The variable cost function is assumed to be increasing and convex. We assume that the total cost is zero when there is no abatement effort, i.e. $C = 0$ when $a_i = 0$ for $i = 1, 2$.

Before analyzing the outcome of negotiations, we first study the non-cooperative game of the countries, which constitutes the threat point of the negotiations.

2.1 Non-cooperative game of the countries

Here we consider a symmetric Nash equilibrium where no country undertakes an abatement effort and no country pays for a fixed cost. This can be the case if the level of fixed cost is sufficiently high. In Appendix B, we define this specific level of the fixed cost and give a numerical example to illustrate it.

At the symmetric Nash equilibrium, no country abates ($\hat{a}_1 = \hat{a}_2 = 0$) and no country pays for a fixed cost. Then, the utility levels of the countries are given only by their initial endowments:

$$\hat{NB}_1 = \hat{NB}_2 = \hat{NB} = \Omega \quad (2)$$

In the next section, we will analyse the reciprocal action case where both countries undertake an abatement effort. Since the countries are identical by assumption, we assume that they have the same negotiation power. So we can focus on the simple Nash bargaining solution, with identical negotiation powers.

2.2 Cooperation: the agreement on a uniform standard without transfer (reciprocal action)

We define the *uniform standard* as $a_1 = \beta_1 \bar{E} = a_2 = \beta_2 \bar{E} = \bar{a} = \beta$ because $\bar{E} = 1$ by assumption. This means that the countries have the same percent-

age reduction rate of their emissions of a base year, which are equal for the countries.

The Nash bargaining solution is written in the following way, when both countries implement an abatement effort:

$$Max_{\bar{a}} \left[\begin{array}{l} (B(2\bar{a}) + \Omega - co - C(\bar{a}) - \hat{N}B) \times \\ (B(2\bar{a}) + \Omega - co - C(\bar{a}) - \hat{N}B) \end{array} \right] \quad (3)$$

Lemma 1 *The uniform standard in the agreement on a uniform standard without transfers is defined by:*

$$B'(\bar{A}) = \frac{1}{2} \times C'(\frac{\bar{A}}{2}) \quad (4)$$

where $\bar{A} = 2\bar{a}$.

Proof. If we note as V the social welfare function 3, the first-order condition with respect to the uniform standard is written:

$$\frac{\partial V}{\partial \bar{a}} = 0 \iff 2 \left[B(2\bar{a}) + \Omega - co - C(\bar{a}) - \hat{N}B \right] \times \left[2B'(2\bar{a}) - C'(\bar{a}) \right] = 0 \quad (5)$$

$$\iff B'(\bar{A}) = \frac{1}{2} \times C'(\frac{\bar{A}}{2}) \text{ where } \bar{A} = 2\bar{a}.$$

■

The resolution of this equation gives us the level of the total abatement, A_U , under the agreement on a uniform standard without transfer. Then one can calculate the utility level for each country:

$$NB_U = B(\bar{A}_U) + \Omega - co - C(\bar{A}_U/2) \quad (6)$$

We now turn to the analysis of the unilateral action case where one of the countries undertakes an abatement effort and pays for the fixed cost of investment, and the other country makes transfer payments.

2.3 Cooperation: the agreement on differentiated standards with transfer (unilateral action)

The *differentiated standard* in this case is $a_1 > 0$ and $a_2 = 0$. This means that country 1 has a positive percentage reduction rate of the emissions and country 2 has no abatement burden. Here, only country 1 abates and country 2 pays a transfer t to compensate country 1. Country 2 has no interest in paying the fixed cost.

The Nash bargaining solution is written in the following way:

$$Max_{a_1, t} \left[\frac{(B(a_1) + \Omega - co - C(a_1) + t - \hat{N}B) \times (B(a_1) + \Omega - t - \hat{N}B)}{(B(a_1) + \Omega - co - C(a_1) + t - \hat{N}B) \times (B(a_1) + \Omega - t - \hat{N}B)} \right] \quad (7)$$

Now, the negotiation variables are the differentiated standard of country 1 and the transfer.

Lemma 2 *The differentiated standard of country 1 is defined by:*

$$B'(a_1) = \frac{1}{2}C'(a_1) \quad (8)$$

Proof. If we note as V the social welfare function 7, the first-order condition with respect to the differentiated standard of country 1 is:

$$\begin{aligned} \frac{\partial V}{\partial a_1} = 0 &\iff [B'(a_1) - C'(a_1)] \times \\ &\left[B(a_1) + \Omega - t - \hat{N}B \right] \\ &= - \left[B(a_1) + \Omega - co - C(a_1) + t - \hat{N}B \right] \times \\ &\left[B'(a_1) \right] \end{aligned} \quad (9)$$

The first-order condition with respect to t is:

$$\begin{aligned} \frac{\partial V}{\partial t} = 0 &\iff \left[B(a_1) + \Omega - t - \hat{N}B \right] = \\ &\left[B(a_1) + \Omega - co - C(a_1) + t - \hat{N}B \right] \end{aligned} \quad (10)$$

The ratio of these two first-order conditions is the following (assuming that we do not divide by zero):

$$\begin{aligned} \frac{(\partial V / \partial a_1)}{(\partial V / \partial t)} &\Longleftrightarrow [B'(a_1) - C'(a_1)] = -B'(a_1) \\ &\Longleftrightarrow B'(a_1) = \frac{1}{2}C'(a_1) \end{aligned} \quad (11)$$

■

The resolution of this equation gives us the level of the total abatement, $a_1 = A_{DT}$, under the agreement on differentiated standards with transfers. So one can calculate the utility level for each country:

$$NB_{1DT} = B(A_{DT}) + \Omega - co - C(A_{DT}) + t \quad (12)$$

$$NB_{2DT} = B(A_{DT}) + \Omega - t \quad (13)$$

In order to calculate the value of the transfer t , we use Condition 10. This gives us:

$$t = \frac{co}{2} + \frac{C(A_{DT})}{2} \quad (14)$$

In the next section, we look at the comparison of the abatement levels under the two institutional arrangements.

3 Comparison of the Abatement Levels

The first-order conditions under the agreement on a uniform standard without transfer and the agreement on differentiated standards with transfers are the following:

- Agreement on a uniform standard without transfer: $B'(\bar{A}_U) = \frac{1}{2} \times C'(\frac{\bar{A}_U}{2})$.
- Agreement on differentiated standards with transfers: $B'(A_{DT}) = \frac{1}{2} \times C'(A_{DT})$.

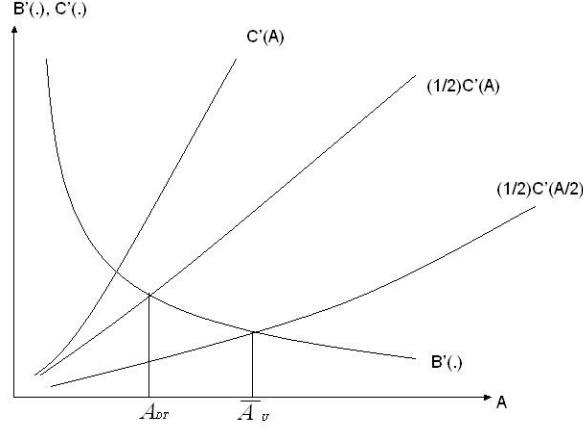


Figure 1: Comparison of the abatement levels

We illustrate, in Figure 1, the abatement levels under these two agreements.

We sum up the comparison of the abatement levels in the following proposition.

Proposition 1 *Given the assumptions on the concavity of the benefit function from global abatement and the convexity of the abatement cost function, we have the following ranking of the abatement standards:*

$$A_{DT} < A_U$$

Proposition 1 says that the countries abate more together when they both make an abatement effort (the case on a uniform standard without transfer) than when only country 1 abates and country 2 compensates it for this effort (the case on differentiated standards with transfers). This finding could be explained by the convexity of the variable abatement cost function.

In the next section, we focus on the comparison of the welfare levels under different institutional arrangements.

4 Comparison of the Welfare Levels

The individual welfare levels of the countries in the agreement on a uniform standard without transfer (U) and the agreement on differentiated standards with transfers (DT) are the following:

- Agreement U: $NB_U = \left[B(\bar{A}_U) + \Omega - co - C(\bar{A}_U/2) \right]$.
- Agreement DT:

$$\begin{aligned} NB_{1DT} &= B(A_{DT}) + \Omega - co - C(A_{DT}) + t \\ NB_{2DT} &= B(A_{DT}) + \Omega - t. \end{aligned}$$

Proposition 2 sums up the main result concerning the comparison of the individual welfare levels in the two agreements. The proof of this proposition is provided in Appendix A.

Proposition 2 *$NB_{1DT} > NB_U$ and $NB_{2DT} > NB_U$ when the fixed cost of investment in the abatement technology is sufficiently high.*

The level of individual welfare in the agreement on differentiated standards with transfers could exceed that in the agreement on a uniform standard without transfer, if the level of fixed cost (co) is sufficiently high. We know from the preceding section that the implementation of the abatement by the two countries (the reciprocal action case) could be explained by the fact that the returns to scale in the abatement technology are decreasing. This case is verified if the level of fixed cost is low; the abatement is carried out in the region of decreasing returns to scale. The analysis of welfare confirms this result. In Appendix B, we exhibit in a quadratic example the level the fixed cost for which the individual welfares of the countries under the agreement on differentiated standards with transfers are higher than those under the agreement on a uniform standard without transfer.

This note shows that strictly identical countries can have an interest in reducing their emissions differently, and not in a uniform way. The explanation of this result comes from the assumption of fixed cost in the abatement technology, which implies a local non-convexity of the abatement cost function. Identical countries could be better off by signing an agreement on differentiated standards with transfers in order to exploit increasing returns to scale in

abatement activities. More specifically, one of the countries abates for both, and pays for the fixed cost of investment. In return, it is compensated by monetary transfers for this effort. We show that the level of the fixed cost must be sufficiently high in this case.

It is important to stress here that we are considering a symmetric Nash equilibrium where no country undertakes an abatement effort and pays for the fixed cost. This implicitly requires a sufficiently high level of fixed cost. It must also be sufficiently low at the negotiation stage to encourage one country to invest, but must be sufficiently high so that only one of the countries invests. In Appendix A, we define this level for quadratic benefit and cost functions. For this precise value of fixed cost, the agreement on differentiated standards with transfers dominates, in terms of individual welfare, the symmetric Nash equilibrium and the agreement on a uniform standard without transfer. A numerical illustration is provided in Appendix B.

5 Conclusion

This note analyzes the welfare comparison between the agreements on uniform versus differentiated standards to control a transboundary pollution problem across two countries. Our findings show that differentiated agreements can be preferred, by identical countries, to uniform ones when the level of fixed cost of investment in the abatement technology is sufficiently high. This result highlights the fact that the argument of similarity of countries to defend the use of uniform standards in international environmental agreements is not always appropriate, especially when one takes into account the level of fixed cost resulting from the installation of an abatement technology.

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APPENDIX

A- Welfare Analysis

We provide here the individual welfare comparison between the agreement on a uniform standard without transfer (U) and the agreement on differentiated standards with transfers (DT) (with $NB_{1DT} = NB_{2DT}$). Given the value of transfers t , the difference between an agreement DT and an agreement U, in terms of individual welfare for each country, is written:

$$\begin{aligned} NB_{DT} - NB_U &= B(A_{DT}) - C(A_{DT}) \times \frac{1}{2} \\ &\quad - B(\bar{A}_U) + C(\bar{A}_U/2) \\ &\quad + co \times \frac{1}{2} \end{aligned}$$

$B(.)$ and $C(.)$ are continuous functions on $[0, 1] \times [0, 1]$ or $[0, 1]$. So $\left[B(A_{DT}) - C(A_{DT}) \times \frac{1}{2} - B(\bar{A}_U) + C(\bar{A}_U/2) \right]$ is finite. Consequently, for a sufficiently large value of co , NB_{DT} is greater than NB_U .

One then can conclude that the countries prefer the agreement on differentiated standards with transfers to the agreement on a uniform standard without transfer if the level of fixed cost of investment co is sufficiently high.

B- Level of Fixed Cost: an example

We look for a specific level of the fixed cost co which satisfies three conditions. First, it must be sufficiently high such that no country abates at the Nash equilibrium. Secondly, it must be high enough to obtain the superiority, in terms of individual welfare, of the differentiated agreement with transfers (DT) over the uniform agreement without transfer (U). Last, it must be low enough such that the countries have higher utility levels in the agreement DT compared to those at the Nash equilibrium. We first analyze the condition which implies that the case where no country abates at the Nash equilibrium is a Nash equilibrium.

At the Nash equilibrium when no country abates, the utility levels of the countries are as follows:

$$\hat{NB}_1 = \hat{NB}_2 = \hat{NB} = \Omega$$

where $\hat{a}_1 = \hat{a}_2 = 0$.

To be a Nash equilibrium, each unilateral deviation must be non-profitable. Suppose that country 1 deviates and abates, the first-order condition for country 1 then becomes $B'(\hat{a}_1) = C'(\hat{a}_1)$.

The utility levels of the countries when only country 1 abates are:

$$\begin{aligned} NB_1 &= B(\hat{a}_1) + \Omega - co - C(\hat{a}_1) \\ NB_2 &= B(\hat{a}_1) + \Omega \end{aligned}$$

One can represent the welfare levels of the countries ($NB_1; NB_2$) in the table below:

	country 2 does not abate
country 1 abates	country 1: $B(\hat{a}_1) + \Omega - co - C(\hat{a}_1)$; country 2: $B(\hat{a}_1) + \Omega$
country 1 does not abate	country 1: Ω ; country 2: Ω

The condition which implies that the case where no country abates is a Nash equilibrium is the following:

$$B(\hat{a}_1) + \Omega - co - C(\hat{a}_1) < \Omega \iff co > B(\hat{a}_1) - C(\hat{a}_1) \text{ (C1)}$$

We now examine the conditions under which the countries have higher utility levels in the agreement DT compared to those at the agreement U and to those at the Nash equilibrium. One can evaluate the utility levels of the countries in the agreement DT using Equation 14, which gives us the expression of the transfer. We obtain:

$$NB_1 = NB_2 = B(a_1) + \Omega - \frac{co}{2} - \frac{C(a_1)}{2}$$

with $B'(a_1) = \frac{1}{2}C'(a_1)$.

The utility levels of the countries in the agreement U are equal to:

$$NB_1 = NB_2 = B(2\bar{a}) + \Omega - co - C(\bar{a})$$

with $B'(2\bar{a}) = \frac{1}{2}C'(\bar{a})$.

The superiority condition of individual welfare for the countries in the agreement DT on the agreement U is written:

$$NB^{DT} > NB^U \iff co > 2B(2\bar{a}) - 2B(a_1) - 2C(\bar{a}) + C(a_1) \text{ (C2)}$$

The superiority condition of individual welfare for the countries in the agreement DT on the symmetric Nash equilibrium is written:

$$NB^{DT} > \hat{NB} \iff co < 2B(a_1) - C(a_1) \text{ (C3)}$$

because $\hat{NB}_1 = \Omega$.

We use quadratic benefit and cost functions:

$$B(a) = \alpha a - \frac{\beta}{2} a^2$$

with $a < \frac{\alpha}{\beta}$.

$$C(a) = \frac{\gamma}{2} a^2$$

where α, β and γ are positive.

We now define the abatement levels associated with these functional forms.

Asymmetric Nash equilibrium

$$B'(\hat{a}_1) = C'(\hat{a}_1) \iff \alpha - \beta \hat{a}_1 = \gamma \hat{a}_1 \iff \hat{a}_1 = \frac{\alpha}{\gamma + \beta}$$

Differentiated standards with transfers

$$B'(a_1) = \frac{1}{2} C'(a_1) \iff \alpha - \beta a_1 = \frac{1}{2} \gamma a_1 \iff a_1 = \frac{\alpha}{\frac{\gamma}{2} + \beta}$$

Uniform standard without transfer

$$B'(2\bar{a}) = \frac{1}{2} C'(\bar{a}) \iff \alpha - 2\beta \bar{a} = \frac{1}{2} \gamma \bar{a} \iff \bar{a} = \frac{\alpha}{\frac{\gamma}{2} + 2\beta}$$

We look for the cases where there exists the specific value of fixed cost co for which Conditions C1, C2 and C3 are simultaneously verified. We allow the parameters α, β and γ to vary between 0.1 and 1 in an interval of 0.1. We observe a high number of cases where these three conditions are verified. For example, with $\alpha = \beta = \gamma = 1$, the three conditions are verified. Because Condition C1 is $co > \frac{1}{4}$, Condition C2 is $co > \frac{2}{15}$ and Condition C3 is $co < \frac{2}{3}$. This means that one can find situations where the agreement DT dominates, in terms of individual welfare, the symmetric Nash equilibrium (no country abates) and the agreement U for the values of the parameters considered.